

# **Evanescence Acoustic Wave Scattering by Targets and Diffraction by Ripples**

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## **LONG-TERM GOALS**

The goal was to develop and test certain ideas relevant to the coupling of sound with small targets buried in the ocean bottom. This was a “Graduate Traineeship Award” in Ocean Acoustics.

## **OBJECTIVES**

The main objective was to understand consequences of incident wave evanescence on (existing or under-utilized) scattering observables. It was also planned to explore conditions whereby surface roughness enhances the coupling of sound to simulated buried targets. Resolving these issues should be helpful for discriminating between echoes from real buried targets and background objects.

## **APPROACH**

Simulation experiments were carried out and the results were compared with theoretical predictions. Professor Philip L. Marston directed the research (while receiving no financial support from this grant). Curtis F. Osterhoudt was a graduate student supported in part by this grant at Washington State University. Osterhoudt completed his Ph. D and is now employed in acoustics research at Los Alamos National Laboratory.

## **WORK COMPLETED**

We previously identified an environmentally-friendly liquid mixture that, when placed in contact with water, has the desirable acoustic contrast to facilitate the production of acoustic evanescent waves in a liquid having a substantial volume. The mixture does not mix with water and is denser than water and typically has a speed of sound of 881 m/s. The emphasis in FY2007 was to continue scattering experiments with a system containing approximately 70 gallons of the dense liquid surrounded by a 3000 gallon water tank. This system was used to generate wavefields having significant evanescent

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components by illuminating the interface with a beam having post-critical incidence. The source transducer was placed in the dense liquid mixture, which simulated the ocean water column. The water in the tank above the mixture simulated the ocean bottom. Hydrophones to detect and measure scattering may be placed either in the water (the simulated bottom) or in the mixture (the simulated water column). In prior Annual Reports [1,2] and presentations [3,4] we demonstrated that several detailed features of the generated wavefield were in agreement with calculations from a wavenumber-based simulation and discussed aspects of the scattering by small targets placed in the wavefield. We showed how resonances of small hollow water-filled cylinders could be excited by using evanescent wave tone bursts having an appropriate frequency [4,5]. The emphasis this year was on the analysis of the response of such targets near a resonance as a function of the frequency of excitation and on the documentation of results from years of research in a Ph. D thesis [6]. Also, a description of the method for generating evanescent waves was submitted for publication [7] and a Final Technical Report was issued [8]. The research extends the understanding of how evanescent waves couple to the low frequency modes of targets and how the resulting radiation reaches the receiver. This research is relevant to interpreting the response of buried targets at low frequencies. Some results will be presented at the 2007 New Orleans ASA meeting [9].

## RESULTS

The evanescent wavefield decays upward in the water since the simulated water column (the oil) is slightly denser than (and is trapped below) the simulated ocean bottom (the water). This is a convenient arrangement since it allows hydrophones and target positions to be easily scanned within the simulated bottom. In our previously reported work we emphasized the exponential decay in amplitude with increasing distance from the interface. During FY2007 we have also confirmed that in the region of the evanescent wave, the *phase* of the wave does not depend on distance from the interface. (This is in agreement with theory [6,7].) At large distances from the interface, however, the aforementioned amplitude and phase behavior breaks down as a consequence of refractive and diffractive processes associated with the finite size of the source. The properties of the wavefield generated in the experiment are discussed in a manuscript submitted for publication [7].

Hanging a small cylinder entirely in the water simulates a cylinder completely buried in sediment. Results obtained by Osterhoudt during FY2007 include detailed modeling of the change in phase and amplitude of the backscattering as the frequency of the exciting tone burst was swept incrementally through the frequency of the fundamental resonance of the system. The physical issue investigated was to determine if both the magnitude and the phase of the response of the water-filled resonant target to evanescent wave excitation would exhibit the kinds of features present for an ordinary forced excitation of a high-Q harmonic oscillator. It was confirmed that the backscattering exhibited a pronounced amplitude peak with a strong dependence of the phase on the frequency of excitation as is the case of an ordinary forced oscillator [6].

## IMPACT/APPLICATIONS

This research should eventually improve the understanding of the acoustic signatures of buried targets and the acoustic discrimination of target and background acoustic scattering. These experiments suggest that in regions where the sediment is smooth it may still be possible to detect certain targets at grazing incidences by relying on the coupling of evanescent waves with low-frequency, high-Q modes of targets.

## RELATED PROJECTS

This Graduate Traineeship Award did not cover materials and supplies costs for this experiment. Those costs were primarily covered by ONR grants N000140310585 and N000140610045. Since most of the funds from this grant were depleted by start of FY2007, Osterhoudt's stipend during the completion of his Ph. D thesis was covered by grant N000140610045.

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- [8] P. L. Marston & C. F. Osterhoudt, Final Technical Report for ONR Award N00014-03-1-0262 (2007); Report DTIC Accession Number ADA471354.
- [9] P. L. Marston, A. L. España, C. F. Osterhoudt, & D. B. Thiessen to be presented (New Orleans ASA meeting).

## PUBLICATIONS

C. F. Osterhoudt, *Evanescent acoustic waves: production and scattering by resonant targets* (Ph. D thesis, Washington State University, May 2007), 283 pages.

C. F. Osterhoudt, D. B. Thiessen, S. F. Morse, & P. L. Marston, "Evanescent acoustic waves from subcritical beam illumination: laboratory measurements near a liquid-liquid interface," [submitted].